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MSW and the Promise of Biotechnology

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When it comes to its progress in achieving zero waste to landfills, the United States is on a par with Slovenia and the Czech Republic.

By James L. Stewart. This article originally appeared in MSW Management and is republished by permission.

On average, the top eight countries in Europe for landfill diversion (Germany, Austria, Belgium, the Netherlands, Switzerland, Sweden, Denmark, and Norway) are putting just 2% of their solid wastes into landfills. Each is recycling and composting at least 50% of its wastes, and collectively they employ 228 thermal waste-to-energy (WTE) plants—exactly one-half of all such plants in Europe—to treat their residuals for energy recovery. Germany and Switzerland now report that they have achieved zero waste to landfills.

The German Federal Environment Agency estimates that the energy generated by its 80 thermal plants saves some 9.75 million tonnes of carbon dioxide emissions (CO2) annually by replacing fossil fuels like coal or oil.

In the US, MSW generation has hovered around 250 million tons per year for the past decade. In recent years, about 35% has been recycled or composted and another 12% has been incinerated for energy recovery. As a nation, we are still landfilling more than half of the solid waste we create.

When it comes to its progress in achieving zero waste to landfills, the US is on a par with Slovenia and the Czech Republic.

In all due respect, despite all best intentions, these facts confirm that the goal of zero waste to landfills cannot be achieved through the recycling of finished products and composting alone.

Admittedly, by tonnage, the primary waste conversion technology in use in Europe and in Asia is now state-of-the-art incineration. Japan, however, is the world's largest user of MSW gasification. It has more than 120 plants that employ gasification-related equipment from companies like JFE, Nippon Steel,

Ebara, Mitsui, Kobelco, and Westinghouse Plasma. Only 2% of Japan's MSW is being disposed of in landfills, a goal that was established out of necessity decades ago, due to their lack of available landfill space and the fact that the transport of MSW from one municipality to another is not allowed.

In less than 20 years, China has become a major player in waste-to-energy, constructing more than 100 WTE plants that process 17% of its MSW. The European and Asian experience compels regulators in North America to modify their definitions of recycling to include not only finished products, but the recovery and reuse of carbon at the molecular level. At a minimum, public jurisdictions should be allowed to obtain landfill diversion credit whenever MSW residuals are converted to syngas (composed primarily of hydrogen and carbon monoxide) and reconstituted into electricity, liquid energy, or biobased chemicals, from which a wide array of biobased products can be produced.

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Such a policy would be consistent with California law, which defines recycling as "the process of collecting, sorting, cleansing, treating, and reconstituting of materials that would otherwise become solid waste, and returning them to the economic mainstream in the form of raw material for new, reused, or reconstituted products, which meet the quality standards necessary to be used in the marketplace," words which the state's bureaucracy has steadfastly refused to put into effect.

A decade ago when the BioEnergy Producers Association was founded, it was widely anticipated that conversion technologies (CTs) would soon meaningfully reduce the nation's dependence upon landfills and contribute to national security, energy independence, and a better environment.

Today, the promise of biotechnology has taken wing. The production of biofuels now extends beyond corn-based ethanol. Last year, POET-DSM, Quad County Corn Processors, Abengoa, and DuPont joined INEOS Bio (whose technology is capable of processing MSW) in commissioning commercial plants that produce cellulosic biofuels from agricultural residues, forest resources and energy crops. Also, during the year, US biodiesel production reached 1.75 billion gallons, and technologies for the production of biobased chemicals moved forward rapidly.

However, the success stories in MSW were few. Only Canada's Enerkem commissioned a commercial scale biorefinery that uses MSW residuals as a feedstock for the production of biofuels and chemicals. It will annually gasify 100,000 dry tonnes of post-recycled solid waste, initially to produce 10 million gallons of biomethanol, a chemical intermediate, and later cellulosic ethanol. It is part of an integrated waste management system for the City of Edmonton where 20% of the city's waste is recycled, 40% is

composted, and 30% is used to produce biofuels. The project has increased the city's landfill diversion rate from 60% to 90%.

7 Reasons why Conversion Technologies have come up short, to date

After a decade-long effort and billions of dollars of expenditure, CTs have yet to fulfill their promise in addressing one of North America's primary environmental goals —reducing the 125 million tons of post-recycled MSW that come to rest in our nation's landfills each year.

Why? The reasons are clear:

1. Nothing discourages capital investment more than *federal regulatory uncertainty*. The Renewable Fuel Standard (RFS), the platform that motivated billions of dollars of private sector investment and enabled the development of the first-generation biofuels industry (ethanol and biodiesel), has been under continuous attack in Congress, as have the federal grant and loan guarantee programs that have supported its development. The $1-per-gallon biodiesel tax incentive, vital to the industry, lapsed at the beginning of 2014, was not retroactively reinstated until December, and several weeks later, was again allowed to expire.

In late May, acting in response to litigation filed by the petroleum industry, the EPA proposed ethanol production levels for 2014, 2015 and 2016. These numbers, which establish the volume of biofuels that must be blended into the nation's transportation fuels under the RFS and which are intended to enable producers to plan production levels that comply with these federally mandated targets, came as many as two years too late to be of any value.

Further, despite acknowledging that Congress, in passing the Clean Air Act, "set targets that envisioned growth at a pace that far exceeded historical growth rates" and that it "clearly intended the RFS program to incentivize changes that would be unlikely to occur absent the RFS program," the EPA proposed an ethanol production level for 2016 that is less than what the industry produced in 2014.

In essence, the conventional fuels industry, by opposing higher blends and limiting its investment in a biofuels distribution and retail marketing infrastructure (the opposite of what the Clean Air Act had intended for it to do), was then able to convince the EPA to rely upon existing distribution capacity as a determining factor in setting its overall biofuels production goals. To summarize big oil's strategy in influencing the EPA's proposal, one might paraphrase the *Field of Dreams*, "If we don't build it, they won't be allowed to come."

As Brent Erickson of BIO noted, “The RFS was designed by Congress to tear down the so-called blend wall by providing a market floor for biofuels that would enable us to attract capital for construction of new biorefineries and commercialization of advanced technologies. Instead, EPA is helping the oil industry build the blend wall to keep advanced biofuels out of the market.”

Bob Dinneen of the Renewable Fuels Association commented, “The EPA plan fundamentally places the potential growth in renewable fuels in the hands of the oil companies — empowering the incumbent industry to continue to thwart consumer choice at the pump with no fear of consequence for their bad behavior.”

In short, the EPA, by acquiescing to big oil’s inaction, has allowed the RFS to become an artificial impediment to increased energy independence.

2. *Commodity price instability:* The past year’s collapse of petroleum prices, mirrored in the price of natural gas, has impacted conversion technology developers as well as first-generation ethanol producers. Vast swings in the price of petroleum, corn, and ethanol, and the value of RINs that track compliance with the RPS have eroded operating margins and discouraged capital investment, and in the past, have caused some first generation biofuels producers to shut down for periods of time. This year’s OPEC-orchestrated petroleum price war has not only been an attempt to slow western oil and gas development, it has been a direct attack on the economic vitality of alternative fuels.
3. *Entrenched opposition:* Aided and abetted by the nation’s livestock, poultry, and food production interests, the oil and gas industry has spent at least $140 million on lobbying in each of the past six years, protecting deep federal subsidies for petroleum, while blaming biofuels for everything from global warming to increasing food prices. Attempts to break through the E10 blend wall have led to the current infrastructure standoff, with the major oil companies resisting the installation of E15 and higher ethanol blender pumps, and advocating the repeal of the RFS.
4. *Price Competition:* Natural gas prices, which are expected to remain depressed over the next decade, have made low-priced fuel and electric power accessible in much of the nation. Further, as opposed to Europe and Japan, landfill capacity and acreage for expansion remains plentiful, keeping tipping fees within reason throughout much of the country.

Last February, Plasco Energy, after investing almost $400 million in its process over 10 years, filed for bankruptcy. According to court documents, Plasco Group engineers “concluded that certain aspects of the conversion system needed to be redesigned in order to sustain commercial operating performance on an economically viable basis…” Concern about “its ability to operate at commercial levels and to convert

both wet and dry waste continuously," and an economic model that relied upon high tipping fees and electric power prices, had long hampered the company's ability to take the technology beyond the demonstration stage.

5. *Consistent, homogenous feedstock* is critical to the MSW conversion process. Conquering this single complexity has slowed commercialization and even defeated some of the industry's most promising technologies. The production of uniform refuse derived fuel is often a necessary intermediary step between recycling and gasification.

In mid-2014, INEOS Bio reported that, since completing construction of its $130 million Vero Beach facility two years earlier, "very little fermentation or production of ethanol from the production fermenter had occurred, due in large part to the sensitivity of the bio-organisms in the fermentation process to high levels of hydrogen cyanide in the syngas." Design modifications, including the installation of HCN scrubbers, resulting from challenges encountered during commissioning delayed nameplate level operations for almost three years. And, this occurred with cellulosic wastes. Mixed MSW has yet to be introduced.

As early as 2012, Coskata, which was founded on the premise of MSW conversion, switched its feedstock strategy to natural gas.

6. *Feedstock aggregation:* Firm feedstock and offtake agreements, contracts for 10 years of more, are normally required for debt financing. Due to the diversity of haulers and waste management contracts in the nation's major markets, MSW feedstock agreements for more than 400 tons per day can be difficult to achieve. The opportunity for CT projects appears to rest in smaller to mid-sized communities, where projects can be developed with individual waste management companies or through public-private partnerships.

In years past, to stimulate the introduction of recycling, local governments and the waste management industry integrated the cost of separating and recovering selected commodities from the MSW stream into the fees they charged to their customers. However, no provision has ever been made for the further recovery and pre-processing of MSW residuals (i.e., RDF units on the back of MRFs) prior to final disposal. The production of uniform feedstocks for biorefineries, established as part of and financed by local integrated waste management systems would go a long way to lifting one of the major technical and economic burdens being experienced by emerging bioindustries. For this to happen, the environmental benefits of such a program would need to be universally recognized by both policy makers and environmentalists, as was the case for traditional recycling. To date, vested interests have effectively prevented this from happening.

7. *State regulatory uncertainty. A number of* state governments, most notably California, have been unwilling to provide developers with a feedstock-driven, technology neutral waste conversion playing field. Although energy recovery or the production of biofuels and biobased chemicals may be a higher and more profitable use of MSW than can be achieved in traditional recycling, this alternative does not appear in many waste hierarchies, nor is this given credit for landfill diversion.

California's astonishing inaction on waste

During the past 10 years, California has landfilled approximately 340 million tons of municipal solid waste, much of which has not even been segregated for standard cans-and-bottles recycling, but instead is collected and sent directly to landfilling. Yet, California's legislature and administration have not taken a single productive step to enable its use as a sustainable feedstock.

Throughout that time, California's own BioEnergy Action Plan has included language directing CalRecycle, its waste management agency, "to work to promulgate changes to existing law to develop a regulatory framework for biomass waste conversion facilities, meeting environmental standards, that clearly distinguishes them from disposal, and provides clear permitting pathways for their development, as well as provides diversion credits to local jurisdictions for solid waste processed by these technologies."

Further, the state's Air Resources Board has acknowledged that organic waste is one of the only feedstocks that, on a life-cycle basis, will meet the emissions reduction objectives of California's Low Carbon Fuel Standard. Its staff once declared that 24 waste-to-biofuels facilities would be required in the state by 2020 to assist in meeting the goals of this program. Its Economic & Technology Advancement Advisory Committee has said that, "By conservative estimates, CTs have the potential to reduce annual greenhouse gas emissions by approximately five million tons of CO2 equivalent in California alone."

And yet, for the past decade, the state's legislative and administrative burueacracy has blocked all efforts to remove from statute a definition of gasification that is universally acknowledged to be scientifically inaccurate. Among its provisions, it requires zero emissions from the entire biorefining process, a physical impossibility and a standard that would shut down every power plant and petroleum refinery in the state. The uncertainty caused by this definition, which governs the regulation of CTs, opens the door to spurious legal challenges by extreme environmentalists, and thus, has caused this emerging industry to turn its back on the state.

Contrast this with Iowa, where, by a combined vote of 136-2, the state's Assembly and Senate have just passed a bill adding waste conversion technologies to a list of preferred waste management techniques for the disposal of solid waste. Its solid waste management policy will now include, "in order of most-preferred to least-preferred, volume reduction at the source, recycling and reuse, waste conversion technologies, combustion with energy recovery, and other approved techniques of solid waste management including but not limited to combustion for waste disposal and disposal in sanitary landfills."

In 2011, California established a policy goal of 75% landfill diversion by 2020, which means that, by that date, it will have to reduce by approximately 10 million tons the amount of material it landfills each year. CalRecycle believes that this can be achieved by requiring universal commercial recycling and convincing the public to further reduce the volume of organics in the residual waste stream. Even if it could possibly achieve this goal, why not reduce the amount of inorganic waste being landfilled, as well, when plasma gasification technologies can turn inorganics into useful products?

The plasma vitrification process offers immense potential for MSW disposal, because it is capable of achieving 100% landfill diversion. Plasma processes operate at temperatures well over 5,000°F, and at these high temperatures, they are able to break down any terrestrial material with an ultra-clean emissions profile. Plasma Power of Ft. Lauderdale, Florida, a leader in plasma technology, has achieved thousands of hours of commercial operation, processing a wide range of waste streams, including MSW, post MRF Residuals, coal ash, drilling waste, ASR, biomass and other industrial waste streams that are hard to remediate. The process is self-powering and able to convert its vitrified product into high value insulation and other green products, resulting in zero waste.

Success stories from around the world

In the United Kingdom, Air Products is constructing two major MSW projects at their Tees Valley Renewable Energy Facility using the advanced Westinghouse plasma gasification technology of Alter NRG. The first of their kind in the UK and the largest of their kind in the world, each will generate 49.9 MW of baseload power, diverting 950 tonnes per day of non-recyclable waste from landfills and producing enough renewable electricity via combined cycle configuration to power the equivalent of 50,000 homes. The first plant is now commissioning and the second, well into construction, is expected to come on line in 2016.

Solena Fuels, in partnership with British Airways, has targeted 2017 for completion of a biorefinery east of London that will annually produce approximately 42 million gallons of sustainable jet fuel and diesel. Solena will employ its patented single-phase, high-temperature plasma gasification system and the modified fixed-bed, microchannel Fischer-Tropsch process of Velocys to convert 575,000 metric tons of

post-recycled MSW, wood waste and agricultural waste to jet fuel and diesel. British Airways has made a long-term commitment to purchase all 17.5 million gallons of the jet fuel produced by the facility each year at market competitive rates.

E2 Environmental Entrepreneurs, in its 2014 Advanced Biofuel Market Report, identified seven companies in the US and Canada that are pursuing technologies capable of producing advanced biofuels from mixed MSW feedstocks. These are defined as technologies whose carbon intensity is at least 50% below that of petroleum, as measured by the California Air Resources Board.

The 2014 E2 report predicted that 34 advanced biofuels plants will be on line by 2017, but only six of these were expected to process MSW, and three of them are projects of Enerkem. Only Fulcrum and Fiberight were expected to commission additional MSW-related biorefineries by that date.

Fulcrum BioEnergy has traveled a long and challenging road in technology development and project finance, but the company has remained firm in its commitment to convert MSW into biofuels, obtaining long-term, zero-cost MSW feedstock commitments representing about 4% of the MSW being landfilled annually in the US.

After initially focusing on ethanol, Fulcrum has moved to the production of a syncrude that can be upgraded to “drop-in” jet fuel or diesel. It will use the steam reforming gasification process of Baltimore-based ThermoChem Recovery International and conventional Fischer-Tropsch technology. Benefiting from commitments for a $105 million USDA loan guarantee and a $70 million grant from the Advanced Drop-in Biofuels Production Project of the Department of Defense, its first plant, now commencing construction east of Reno, Nevada, will annually consume 147,000 tons of zero-cost MSW to be delivered by Waste Management and Waste Connections. Aware of the need for gasification feedstock consistency, Fulcrum is building its own pre-processing facility onsite.

Fiberight has operated a demonstration facility in Lawrenceburg, VA, for more than 5,000 hours, that involves MSW feedstock pre-treatment, including pulping, and enzymatic hydrolysis to produce industrial sugars that can be sold as is or fermented to produce ethanol. After EPA ruled that CNG produced from biogas qualifies as advanced biofuel and for D3 RINs, Fiberight put on hold its plans to convert organic residuals to ethanol at its shuttered Blairstown, IA, ethanol plant, and now plans to employ anaerobic digestion to produce CNG from C5 sugars at a 300 ton-per-day MSW shredding and sorting facility in Marion, IA. In Maine, it is pursuing the same concept, only larger, through a public-private partnership formed to process the MSW of 187 mid-coast communities.

In the past two years, substantial development capital and research have been focused on biobased chemicals and bioplastics, where prices and margins are more attractive, markets are more stable, and the plant-based feedstocks used to create C5 ad C6 sugars are less vulnerable to the commodities speculation we have experienced with petroleum and corn. Renewable chemicals and biobased products face a less intrusive federal regulatory environment than biofuels, and they are now eligible for loan guarantees.

However, one promising biobased chemicals producer that remains focused on MSW is Kiverdi. Among its feedstocks, Kiverdi can gasify MSW as its first step in producing high-value oils and chemicals for such product applications as detergents, biomaterials and fuel additives. Its proprietary high-yield microbes can sustainably produce high quantities of oils from waste carbon, decoupled from the price fluctuations, supply chain disruptions and geopolitics associated with commodities.

So, what does this mean for waste managers who are beginning to think about options for the future?

It means be patient. Look for modular technologies that can easily be replicated, ones that are feedstock flexible and capable of creating multiple revenue streams. “Drop-in” fuels—those with the same molecular structure as refined petroleum, that can be transported through existing pipelines, that can be blended with or replace petroleum-based fuels without regulatory limitation—will have an easier time entering the marketplace. Some version of California’s LCFS will one day be adopted by other states across the nation, and MSW-based drop-in fuels will be well positioned to help achieve their goals.

A recent study by Columbia University’s Earth Engineering Center estimated that if all of the MSW that is being landfilled in the United States were converted to power, it could generate enough coveted base load power to serve nearly 14 million homes, or 12% of the nation’s total. It would reduce greenhouse gas emissions by at least 123 million tons of carbon dioxide equivalents per year, an amount comparable to taking more than 23 million cars off the road.

Viewed another way, the organic materials that America places in landfills each year contain the energy equivalent of approximately 240 million barrels of oil.

Worldwide, there is enough MSW available to produce 42 billion gallons of cellulosic biofuels.

It has been estimated that energy recovery will ultimately generate 70% of the revenue attributable to next-generation waste management technologies in North America.

The industry has embarked on a paradigm shift. By the end of this decade, the ability to recycle MSW's carbon content at its molecular level will be seen as an asset, a strategic resource in a circular economy.

So, stay the course. Take an active part in the political process. The logic of recovering the energy value in the nation's MSW residuals—before they are placed in landfills — will ultimately prevail. **MSW**

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